

PALEOGENE INSECT FAUNAS OF WESTERN NORTH AMERICA¹.

M. V. H. WILSON

Department of Zoology

University of Alberta

Edmonton, Alberta

T6G 2E9

Quaestiones Entomologicae

14: 13–34 1978

North American Paleogene insect faunas are concentrated in lacustrine sediments of the Cordillera. They represent cool temperate to tropical paleoclimatic conditions, yet were deposited at paleolatitudes somewhat farther north than present latitudes. The more than 200 insect families recognized are listed, with supporting references. Only about 90 of these have geological ranges extending back to Paleocene or Eocene times. The faunas are dominated by Coleoptera, Hymenoptera, and Diptera, especially Bibionidae (Plecia spp.).

Les insectes du Paléogène de l'Amérique du nord sont concentrés dans les sédiments lacustres de la Cordillère. Ces sédiments, déposés à des latitudes légèrement plus au nord qu'aujourd'hui ont des faunes de climat tempéré à tropical. Plus de 200 familles sont reconnues pour cette période et notées avec leurs références. Seulement 90 de ces familles se rencontrent aussi tôt que le Paléocène ou l'Eocène. Les faunes sont dominées par les Coléoptères, les Hyménoptères, et les Diptères (particulièrement les Bibionidae du genre Plecia).

INTRODUCTION

North American Paleogene (Early Tertiary) insect faunas were first studied comprehensively by S.H. Scudder (1890a, d, and references therein). Although more than 150 papers dealing with these faunas have since been published, the faunas have not recently been summarized.

This paper presents a summary of known Paleogene insect localities, a faunal list at the family level and a bibliography to the relevant literature. Compilation was carried out using Zoological Record searches together with cross-referencing from literature cited sections of included papers. It is hoped that this summary of the faunas will promote their further study and thus enhance their usefulness for reconstruction of paleoenvironments and faunal evolution.

PALEOGENE INSECT FAUNAS

Paleogene insect localities in North America are distributed in a broad band from British Columbia southeastward to Colorado (Fig 1). The insects are preserved as compressions in shale or other fine-grained rocks, and often occur with fossil leaves and fishes. The sediments and associated fossils indicate deposition in quiet water regions of intermontane lakes. The location, age, composition, and paleoenvironment of the major faunas are discussed below.

Paleocene Faunas

Paleocene insect localities are rare in North America and their faunas have been little studied. They occur in the Great Plains, in fine-grained phases of sedimentary formations which are otherwise predominantly coarse-grained. Brown (1957, 1962) mentioned and figured specimens of Trichoptera, Blattodea, and Odonata from localities 19, 20 and 21 respectively (Fig 1) in Fort Union strata of Montana, and mentioned coleopterous elytra as being abundant at other Paleocene localities. Also from the Fort Union of Montana, Cooper (1941) described a specimen of Cicadidae from near Bear Creek, Montana (Fig. 1, locality 27). This cicada was found in association with mammals and with plants which indicate a lowland, humid, warm-temperate paleoenvironment (Cooper, 1941). Recently insects have also been discovered in the Paleocene Paskapoo

¹Invitation paper, submitted on request of the editor.—GEB

Formation near Red Deer, Alberta (Fig. 1, locality 22). These latter collections were obtained by D. Wighton and P. Mitchell of the University of Alberta. Taxa recognized to date from locality 22 include Odonata - Gomphidae; Homoptera - Cercopidae; Coleoptera - Carabidae, Dytiscidae, Chrysomelidae, Tenebrionidae; and some unidentified larvae (Wighton and Mitchell, pers. comm.). In addition, University of Alberta paleontologists have discovered a case of Trichoptera - Limnephilidae? associated with fishes and molluscs in the Paskapoo Formation near Robb, Alberta (Fig. 1, locality 25), a case of Trichoptera - Leptoceridae? from the same formation near Edson, Alberta (Fig. 1, locality 26), and tegmina of Homoptera - Fulgoroidea from the same formation near Sundance, Alberta (Fig. 1, locality 28). Little is known in detail about the age or paleoenvironments of most of the Paleocene faunas.

Eocene Faunas

A: Green River—The Green River Formation occurs in several sedimentary basins in Wyoming, Utah, and Colorado (Fig. 1). As there are many individual localities in the Green River Formation which are not well known they are listed below. In Wyoming, two localities occur in the Green River Basin (Fig. 1, localities 8 and 10), occupied during the Eocene by Gosiute Lake (Schaeffer and Mangus, 1965). A third locality is in the much smaller Fossil Basin (locality 9) formerly occupied by Fossil Lake (McGrew and Casilliano, 1975). Those localities in Colorado (localities 4-6) are in the Piceance Creek Basin while the locality in Utah near the Colorado border (locality 7) is in the Uinta Basin. The Piceance Creek and Uinta Basins were both occupied by Eocene Lake Uinta (Schaeffer and Mangus, 1965).

Most of the Wyoming Green River insects described by Scudder (1890a) and others apparently came from red shales at the Fish Cut locality near Green River, Wyoming (Fig. 1, locality 8). Relatively few came from the Fossil Butte locality (locality 9; McGrew and Casilliano, 1975), and only caddisfly cases are known from Leucite Mountain (locality 10; Bradley, 1924, 1974).

In the Piceance Basin of Colorado, locality 4 (Fig. 1) represents a large number of sites in the Roan Plateau area, including Piceance Creek of Carpenter (1928, 1931, 1955), Kimball Creek of James (1932), and the Brushy Creek Canyon, Parachute Creek, Roan Mountain, Rifle, Eask Alkali Gulch, Camp Gulch, and Bear Gulch sites of Cockerell (1909d, 1921a-c, 1923a, 1925a, 1925c, 1928, 1933, 1941) and Cockerell and LeVeque (1931.) Locality 5 is Hay Gulch of Cockerell (1917a), and locality 6 represents the Smith's Ranch, Little Duck Creek, and Cathedral Bluffs sites of Cockerell (1921a, b, 1925a), and the Douglas Pass site (University of Alberta collections).

Scudder described many insects from a locality he termed "White River", a designation which is unfortunate because of possible confusion with the Oligocene White River Group of Colorado. Scudder's "White River" collections, some of which were described by Cockerell (1921a, b) came from Green River Formation localities along the White River near the Colorado-Utah border (locality 7). These may correspond in part to the Evacuation Creek localities of Cockerell (1916) and Carpenter (1955) in the Uinta Basin.

The Green River Formation strata are dated by their intercalation with the mammal-bearing Wasatch and Bridger Formations. Recent stratigraphic studies indicate that the Green River Formation in the Green River, Fossil and Piceance Basins ranges in age from Late Early Eocene (Lostcabinian) to Late Middle Eocene (Bridgerian C-D), or from about 52Ma to about 47Ma BP (Roehler, 1972). Some Green River strata in the Uinta Basin may be slightly younger.

Table 1 gives the composition to family level of the Green River Formation fauna. A total of 83 families has been recorded. By 1921 Cockerell could mention 279 species (Cockerell 1921a). In number of individuals, Cockerell noted the abundance of Coleoptera, Diptera, Hymenoptera, and Homoptera (especially Fulgoridae; Cockerell 1917c, 1921a). Scudder (1890c) earlier tabulated the results of a single summer's collecting effort and showed that the majority of specimens from the Green River localities were Coleoptera (63%), followed by Diptera (22%) Hemiptera - Homoptera (9%), and Hymenoptera (3%). Lepidoptera are rare, and bees have yet

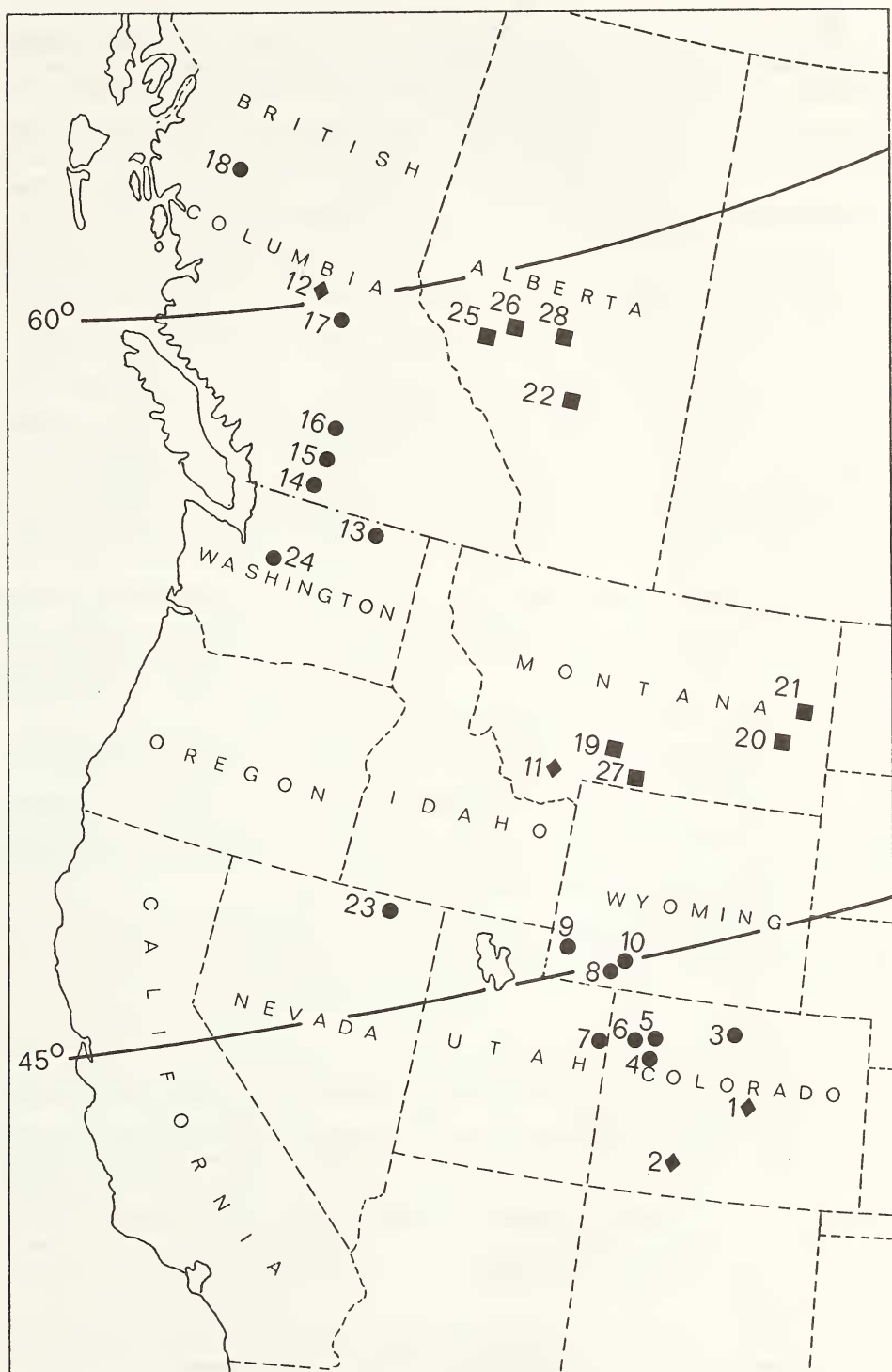


Fig. 1. Distribution of Paleogene insect localities in western North America. Squares are Paleocene localities, circles are Eocene localities, and diamonds are Oligocene localities. Heavy oblique lines are reconstructed Eocene latitudes. Locality numbers are referred to in text.

to be discovered. Cockerell remarked on the absence of really large specimens, the average size being smaller than the insects of the Florissant shales. He also commented on the relatively few species in common between the Green River Basin and the Colorado-Utah basins.

It has been thought until recently that much of the oil shale and varved fossiliferous marl of the Green River Formation was deposited in the deeper regions of stratified lakes (Bradley, 1948; McGrew, 1975). More recently playa-lake (Eugster and Surdam, 1973) and near-shore depositional environments (Bradley, 1974; Baer, 1969; Buchheim and Surdam, 1977) have been proposed, and many workers now feel that much of the Green River Formation represents playa-lake deposition (Eugster and Hardie, 1975; Surdam and Wolfbauer, 1975). Even if this is true, both deep and shallow phases are undoubtedly represented, as evidenced by major differences between such fish faunas as those of the Fossil Butte locality (McGrew, 1975) and others near Green River, Wyoming (Buchheim and Surdam, 1977). It is not known what proportion of the insect fauna occurs in the deep water deposits. Paleobotanical evidence suggests that climates during deposition of the Green River Formation varied from tropical to subtropical (Leopold and MacGinitie, 1972). Paleolatitudes reconstructed from Eocene paleomagnetic pole positions relative to North America (Jurdy and Van Der Voo, 1975) suggest that the Green River Formation localities were at a latitude of about 45° during the Eocene (Fig. 1). The Green River Formation is also famous for its fossil fishes (McGrew and Casilliano, 1975; Buchheim and Surdam, 1977).

B. British Columbia.—The Eocene insect fauna of British Columbia has recently been summarized with specific locality information by Wilson (1977b). There are numerous localities, representing isolated Eocene lakes, scattered through the interior plateau region of the province (Fig. 1, localities 14-18). Early studies of the fauna were by Scudder (1890a, 1895) and Handlirsch (1910); more recent studies were by Rice (1959, 1968).

Associated mammal teeth and palynomorphs, and K-Ar dating of interbedded volcanics indicate that the sediments are Middle Eocene or about 47-52 Ma old (Wilson, 1977b).

The fauna contains representatives of 30 families in seven orders (Table 1). In numbers of individuals it is dominated by Bibionidae of the genus *Plecia*, although locally Gerridae, large Homoptera, and Ichneumonidae are abundant. Coleoptera are rare except at one locality (Fig. 1, locality 15), from which they are the only order so far reported.

Specimens are preserved in fine-grained tuffaceous shales which appear to represent both deep off-shore and shallow, near-shore paleoenvironments. The varved insect-bearing sediments in the Horsefly area (Fig. 1, locality 17) were deposited in deep water in the hypolimnion of a stratified lake (Wilson, 1977a). Associated fossils such as molluscs, fishes, and coal at other localities indicate shallow, swampy conditions (Wilson, 1977b). The local insect faunules appear to reflect these paleoenvironmental differences (Wilson, 1977b).

According to paleobotanical evidence, the Middle Eocene climate in British Columbia was warm temperate, with wet summers and dry winters, and more continental aspects than Eocene coastal climates at the same latitude (Rouse et al., 1971). Eocene forests in British Columbia are believed to have been of a mixed deciduous-coniferous composition. Reconstructed paleolatitudes (Fig. 1) suggest that the area was at a latitude of about 60°N during the Eocene, or about 15° farther north than the area of the approximately contemporaneous Green River fauna. The insects occur with leaves, fishes, molluscs, and rare spiders, birds, and mammals (Wilson, 1977b, 1977c).

C. Republic, Washington—Insects are also known from the Middle Eocene Klondike Mountain Formation near Republic, Washington (Fig. 1, locality 13). A few specimens were obtained by R.C. Pearson of the U.S. Geological Survey in the 1960's. In addition, a sizable collection was obtained by the present author during fossil fish collecting expeditions in 1976 and 1977. This collection is now at the University of Alberta. No studies of the Republic insects have yet

been published.

The Republic flora, described by Berry (1929) and Brown (1937), was believed until recently to be Oligocene. Its Middle Eocene age is based on a number of K-Ar determinations on inter-bedded volcanics (R.C. Pearson, pers. comm., 1976). The fossil fishes are consistent with this interpretation (Wilson, in press). The Republic fauna is the same age as the British Columbia fauna, and is probably best interpreted as a southward extension of it.

The University of Alberta collections have yet to be studied in detail, but like the contemporaneous British Columbia fauna they contain numerous specimens of Bibionidae (*Plecia*) and large-winged Homoptera.

Sedimentology and study of associated fossil fishes indicate the presence of both deep water and shallow water conditions. In other aspects the paleoenvironment is probably similar to the British Columbia conditions of the time.

D: Coalmont Formation.—Cockerell (1916) described Eocene insects from the North Park Colorado, near Big Muddy (or Araphahoe) Pass. In 1977 the author obtained a collection, now at the University of Alberta, from the Coalmont Formation in this area.

The age of this fauna is probably Early Eocene. Palynomorphs studied by Leopold (Leopold and MacGinitie, 1972) indicate that the Coalmont Formation is Paleocene and Early Eocene. Fossil leaf occurrences in the Coalmont Formation are believed to be Eocene (Hail, 1965).

Cockerell's (1916) insects were assigned to two species of Coleoptera. The University of Alberta collection has yet to be studied, but it is dominated by Coleoptera as well.

Contemporaneous floras in Wyoming indicate a humid, subtropical paleoclimate (Leopold and MacGinitie, 1972). The insects occur in association with fishes (University of Alberta collections).

E. Additional Eocene faunas.—Other Eocene faunas have been collected by this author, but as yet have been little studied. So far only coleopterous elytra have been found.

These faunas include the Copper Basin fauna which occurs in the Dead Horse Tuff near Jarbidge, Nevada (Fig. 1, locality 23). Its Late Eocene age is based on a K-Ar date of 40 Ma BP (Axelrod, 1966). The Copper Basin flora is dominated by conifers and small-leaved angiosperms, representing a cool-temperate upland habitat (Axelrod, 1966).

The Roslyn fauna occurs in the Roslyn Formation near Cle Elum, Washington (Fig. 1, locality 24). It is considered to be Middle Eocene based on a single fossil fish and two turtle carapaces (Foster, 1960). The insects occur with leaves and molluscs in shales roofing a coal seam, indicating shallow, swampy depositional conditions.

Oligocene Faunas

A: Florissant.—The Florissant fauna is the best known, most prolific, and most diverse of the North American Paleogene insect faunas. There are a number of localities within a small intermontane basin (Scudder, 1882) once occupied by a small lake near South Park, Colorado (Fig. 1, locality 1). Many people, including Scudder and Cockerell, have published descriptions of Florissant insects.

The shales of the Florissant basin are generally agreed to be Early Oligocene. This age is based on study of plants (Leopold and MacGinitie, 1972) and of a marsupial (Gazin, 1935).

The fauna as presently known includes representatives of 192 families (Table 1). According to Scudder (1882, 1890c) there are many specimens of Formicidae and Ichneumonidae among the Hymenoptera, and of Bibionidae among the Diptera.

The Florissant shales seem to have been deposited in part in the hypolimnion of a stratified lake (McLeroy and Anderson, 1966). The Early Oligocene climate of the Florissant area was warm temperate to subtropical according to the evidence of fossil floras (Leopold and MacGinitie, 1972). The insect evidence is in accord with this interpretation, but the evidence is

conflicting as to whether the climate was wet or dry. For example, James (1939) felt that some of the Diptera were indicative of a humid climate, whereas the abundance of Bombyliidae (Hull, 1973) suggests an arid climate. The small intermontane basin is indicative of a more upland location than the older Green River lakes. The paleolatitude of the Florissant shales was probably little different from that of the Green River Formation (Fig. 1).

B: Mormon Creek.—The Mormon Creek fauna (Fig. 1, locality 11) is the smaller of two known from the Passamari Formation of the Ruby Basin, Montana (Dorr and Wheeler, 1964). The Mormon Creek sediments cover only a small area and specimens are obtained primarily from a single excavation site.

The Flora is indicative of a Late Eocene or Early Oligocene age (Leopold and MacGinitie, 1972) although ages as old as Late Early Eocene have been suggested (Becker, 1960).

Only a few insects from this fauna have been reported. They include Carabidae, Tipulidae, and Ichneumonidae (Becker, 1960).

The plants indicate a humid, warm temperate to subtropical climate and moderate elevation (Becker, 1960). The Mormon Creek fauna also includes fish scales (Becker 1960; University of Alberta collections).

C: Ruby Paper Shales.—The Passamari Formation of the Ruby Basin, Montana (Fig. 1, locality 11), contains a second insect fauna believed to be Late Oligocene (Leopold and MacGinitie, 1972; Dorr and Wheeler, 1964). The Ruby Paper shales are found at a number of excavation sites in a small area between Mormon and Peterson Creeks in the Upper Ruby River Basin (Becker, 1961).

The insect fauna includes representatives of 29 families in 13 orders, according to Becker (1961, 1965), Hull (1960, 1962), Lewis (1971a, 1971b, 1972, 1975, 1976), and Zuidema (1950, 1955). Recognized are: Ephemeroptera - Baetidae; Odonata; Dermaptera; Plecoptera; Orthoptera - Acrididae; Hemiptera - cf Coreidae; Homoptera - Cicadellidae, Fulgoridae; Megaloptera - Sialidae, Corydalidae; Coleoptera - Silphidae?, Scarabeidae, Psephenidae, Elateridae; Diptera - Tipulidae, Chironomidae, Bibionidae, Mycetophilidae, Therevidae, Asilidae, Bombyliidae, Diopsidae, Syrphidae; Mecoptera; Trichoptera; Lepidoptera - Psychidae?; Hymenoptera - Tenthredinidae?, Ichneumonidae, Apidae, Formicidae. Bibionidae are the most abundant Diptera (Hull, 1960), as at many other Paleogene localities.

According to Becker (1961, 1966) and Leopold and MacGinitie (1972) the Ruby flora records cooler conditions than at Florissant, but still warmer, more moderate, and more moist than in the modern Ruby Basin. The insects occur in association with the diverse Ruby Paper Shale flora (Becker, 1961, 1966) and with fishes and a bird (Becker, 1961; Dorr and Wheeler, 1964).

D: Creede.—The Creede Formation of Colorado (Fig. 1, locality 2) is believed to be latest Oligocene or earliest Miocene in age (Leopold and MacGinitie, 1972).

Insects from the formation include Isoptera - Rhinotermitidae; Megaloptera - Raphidiidae; Neuroptera - Chrysopidae; Diptera - Tipulidae, Bibionidae, Syrphidae; Hymenoptera - Ichneumonidae (Carpenter, 1935, 1936; Carpenter et al., 1938; Cockerell, 1941). The Chrysopidae, Tipulidae, and Bibionidae are among the most abundant based on lists of specimens in Carpenter et al. (1938).

Floral evidence suggests a high altitude paleoenvironment (Leopold and MacGinitie, 1972). According to Carpenter et al. (1938) this is reflected in the low specific diversity of the insect fauna.

E: Quesnel.—Tertiary insects from the Fraser River Valley near Quesnel, British Columbia (Fig. 1, locality 17) were described by Scudder (1890a, 1895) and Handlirsch (1910).

There has been no dating of the specific fossil localities. However, Late Early Oligocene mammal teeth and palynomorphs occur in Fraser Valley sediments south of Quesnel (Piel, 1971).

Table 1. Systematic list of insect families known from three Paleogene faunas. References for each family are combinations of the last two digits of the year of publication, and the author's surname abbreviated as follows: Ben: Benson; Be: Bequaert; Br: Bradley; Bn: Brown; B: Brues; Ca: Carpenter; C: Cockerell; CC: Cockerell and Custer; CL: Cockerell and LeVeque; Co: Cooper; E: Emerson; F: Forbes; Ha: Handlirsch; H: Hull; J: James; M: Melander; MC: McGrew and Casilliano; Ri: Rice; R: Rohwer; S: Scudder; Sn: Snyder; W: Wickham; Wi: Wilson; ZM: Zeuner and Manning.

Order	Family	Common Name	Florissant	Green River	British Columbia	References
Thysanura						
	Lepismatidae	silverfish	x			C13d, S90a
Ephemeroptera						
	Baetidae	small may flies	x			C23b
	Ephemeridae	burrowing mayflies	x			C08j, C13d, S86, S90a
Odonata						
	Platycnemididae	platycnemidid damselflies	x			C08i, S92a
	Coenagrionidae	narrow-winged damselflies	x			BMC54, C21a, C25b
	Chlorocyphidae	chlorocyphid damselflies		x		C25a
	Calopterygidae	broad-winged damselflies	x	x		C07d, C08a, C08i, C08q, C08t, C09d, C10 C13d, C16, C21a, C25b, C40, S90a
	Aeshnidae	darners	x			C07d, C13c, C13d, S90a
	Gomphidae	clubtails	x			S92a
	Libellulidae	common skimmers	x	x		C21b, S78, S90a
Blattodea						
	Blattidae	cockroaches	x	x	x	Bn57, Ca47, C09g, C13d, S86, S90a
Mantodea						
	Mantidae	mantids	x			C08f, C13d
Dermaptera						
	Forficulidae	common earwigs	x			C25a, S86, S90a
Orthoptera						
	Gryllacrididae	leaf-rolling grass-hoppers	x			C09h, S90a
	Tettigoniidae	long-horned grass-hoppers	x			C08m, C09h
	Gryllidae	crickets	x	x		C08a, C21b, S78, S86, S90a
	Acrididae	short-horned grass-hoppers	x	x	x	C08a, C09h, C10, C14b, C26b, Ha10, S78, S86, S90a
Phasmatodea						
	Phasmatidae	walking sticks	x			C13d, S86, S90a
Embioptera						
	Embiidae	webspinners	x			C08j, C13d
Isoptera						
	Mastotermitidae	mastotermitids			x	Wi77b
	Kalotermitidae	dry-wood, damp-wood, powder-post termites	x			E33, E69, S90a, Sn25, Sn50
	Termopsidae	true damp-wood termites	x			E33, Sn25
	Hodotermitidae	rotten-wood termites	x			C13e, S86, S90a, Sn25, Sn50

Table 1. (Continued.) Systematic list of insect families known from three Paleogene faunas. Abbreviations p. 19.

Order	Family	Common Name	Florissant	Green River	British Columbia	References
Psocoptera	Rhinotermitidae	subterranean and damp-wood termites	x			S90a, Sn25, Sn50
	Termitidae	soldierless, desert and nasutiform termites	x			C13d, Sn25
Hemiptera		booklice, psocids		x		S90a
Homoptera	Miridae	leaf (plant) bugs	x			C13d, S90a
	Tingidae	lace bugs	x			C14a, S90b
	Reduviidae	assassin bugs	x	x		S78, S90a
	Coreidae	leaf-footed bugs	x	x		C09d, S90a, S90b
	Saldidae	shore bugs		x		S90a
	Lygaeidae	seed bugs	x	x		S78, S90a, S90b
	Pyrrhocoridae	red bugs or stainers	x			S90a
	Cydnidae	burrower bugs	x	x		C09d, S90a
	Pentatomidae	stink bugs	x	x	x	C09g, C26c, S78, S90a, Wi77b
	Gerridae	water striders	x	x	x	C13d, Ha10, S90a, S95, Wi77b
	Veliidae	ripple bugs	x		x	S90a, Wi77b
	Gelastocoridae	toad bugs		x		S90a
	Notonectidae	back swimmers	x			S90a
	Belostomatidae	giant water bugs	x			C08j
	Corixidae	water boatmen	x			S90a
	Cixiidae	cixiid planthoppers	x	x		S90a
	Delphacidae	delphacid planthoppers		x		C25a, S90a
	Fulgoridae	planthoppers	x	x	x	C09d, C09g, C21a, C21c, CL3l, S78, S90a, S95
	Achilidae	achilid planthoppers	x			S90a, S90b
	Ricaniidae	ricaniid planthoppers		x		S90a
	Flatidae	flatid planthoppers		x		C21a, S90a
Thysanoptera	Dictyopharidae	dictyopharid plant-hoppers	x			S90a
	Cercopidae	froghoppers, spittlebugs	x	x	x	C08s, C21a, Ha10, S90a, S90b, S95, Wi77b
	Cicadidae	cicadas	x			C06a, C08h, C11, C13d, C17b, Co41, S92a
	Cicadellidae	leafhoppers	x	x	x	Ca47, C13d, C21a, C25a, S78, S90a, S95, Wi77b
	Psyllidae	psyllids or jumping plantlice	x			C11, C14b, S90a
	Aphididae	aphids or plantlice	x	?		C08n, C09g, S90a
	Pemphigidae	woolly and gall-making aphids	x	x		S90b
	Coccidae	wax and tortoise scales	x			C13d, S90a
	Aeolothripidae	broad-winged or banded thrips		x		S90a
					x	Wi77b
					x	S90a
					x	Ca36, C07a, C09g, C12, C13d, C14a, C17b, CC25, Ha10, R09

Table 1. (Continued.) Systematic list of insect families known from three Paleogene faunas. Abbreviations p. 19.

Order	Family	Common Name	Florissant	Green River	British Columbia	References
Neuroptera	Inocelliidae	inocelliid snakeflies	x			Ca36, CC25
	Hemerobiidae	brown lacewings	x			C08a, C08e, S90a
	Chrysopidae	green lacewings	x			Ca35, C08c, C09e, C14a, S90a
Coleoptera	Nemopteridae	nemopterids	x			C07b, C08r
	Carabidae	ground beetles	x	x	x	C08h, C13d, C21a, C21b, C25a, S78, S90a, S92a, S95, S00, W09, W11, W13, W14b, W17, W20
	Cicindelidae	tiger beetles		x?		C21a
	Dytiscidae	predaceous diving beetles	x	x		S90a, S00, W09, W11, W13, W14b, W20
	Hydrophilidae	water scavenger beetles	x	x	x	S78, S90a, S95, S00, W09, W11, W14b, W20
	Silphidae	carrion beetles	x			C08a, S00, W13, W14b, W20
	Staphylinidae	rove beetles	x	x		S90a, S00, W11, W13, W14b, W20, W11, W13, W20
	Lucanidae	stag beetles	x			Ha10, S90a, S95, S00, W09, W11, W13, W14a, W14b, W20
	Scarabeidae	scarab beetles	x	x	x	W20
	Helodidae	marsh beetles	x			W11, W14b, W20
	Dascillidae	soft-bodied plant beetles	x			S92a, W13, W14b, W20
	Byrrhidae	pill beetles	x			S90a, S00
	Nosodendridae	wounded-tree beetles		x		W20
	Psephenidae	water penny beetles	x			W20
	Chelonariidae	chelonariid beetles	x			W20
	Dryopidae	long-toed water beetles	x			S00, W11, W14b
	Buprestidae	metallic wood-boring beetles	x		x	C26c, S90a, S95, S00, W13, W14a, W16, W17, W20
	Elateridae	click beetles	x	x	x	C14b, CL31, Ha10, S78, S90a, S95, S00, W08, W14b, W16, W20
	Eucnemidae	false click beetles	x			W20
	Trixagidae	throsoid beetles	x			W14a, W20
	Lampyridae	lightningbugs or fire-flies	x			S00, W13, W14b, W17, W20
	Cantharidae	soldier beetles	x			W09, W20
	Lycidae	net-winged beetles	x			W20
	Melyridae	soft-winged flower beetles	x			C13d, W14b, W17
	Dermestidae	dermestid or skin beetles	x			S00, W14b, W20
	Anobiidae	death watch beetles	x	x		W20
	Ptinidae	spider beetles	x	x		S78, S90a, S92b, S00, W14a, W14b, W17

Table 1. (Continued.) Systematic list of insect families known from three Paleogene faunas. Abbreviations p. 19.

Order	Family	Common Name	Florissant	Green River	British Columbia	References
	Bostrychidae	branch and twig borers	x			W14b, W20
	Trogossitidae	bark-gnawing beetles	x			C13d, W13, W20
	Cleridae	checkered beetles	x			W14a, W14b, W20
	Lymexylidae	ship-timber beetles	x			W11, W20
	Nitidulidae	sap beetles	x	x		S78, S90a, S00, W20
	Cucujidae	flat bark beetles	x	x		S90a, S00, W13, W14a, W14b, W20
	Cryptophagidae	silken fungus beetles	x	x		C26c, S78, S90a, S00, W13, W14b, W20
	Erotylidae	pleasing fungus beetles	x	x		S78, S90a, S00, W20
	Coccinellidae	ladybird beetles	x			S00, W14b, W17, W20
	Lathridiidae	minute brown scavenger beetles	x			W14a, W14b, W20
	Mycetophagidae	hairy fungus beetles	x			W20
	Colydiidae	bark beetles	x			W14b, W20
	Tenebrionidae	darkling beetles	x		x	S90a, S95, S00, W13, W14a, W20
	Alleculidae	comb-clawed beetles	x			W14a, W14b, W20
	Pythidae	narrow-waisted bark beetles	x			W20
	Melandryidae	false darkling beetles	x	x		C25a, W11, W20
	Mordellidae	tumbling flower beetles	x	x		C25a, W09, W14a, W14b, W20
	Rhipiphoridae	wedge-shaped beetles	x	x		S78, S90a, S00, W20
	Oedermeridae	false blister beetles	x			W14b, W20
	Meloidae	blister beetles	x			S00, W14b, W20
	Anthicidae	antlike flower beetles	x			W14b, W20
	Cerambycidae	long-horned beetles	x	x		C08a, C08i, C16, C25a, S00, W11, W13, W14a, W14b, W17, W20
	Bruchidae	seed beetles	x	x		S90a, S00, W13, W14b, W17, W20
	Chrysomelidae	leaf beetles	x	x	x	C21a, S78, S90a, S95, S00, W11, W13, W14a, W14b, W20
	Anthribidae	fungus weevils	x	x		S78, S90a, S92b, S93, W11, W14b, W20
	Attelabidae	leaf-rolling beetles	x	x		C13d, S90a, S92b, S93, W11
	Curculionidae	snout beetles	x	x		C09i, C13d, C21b, C26c, S78, S90a, S92b, S93, W11, W13, W14b, W17, W20
	Scolytidae	bark or engraver and ambrosia beetles	x	x		S78, S90a, S92b, S93, W11, W20
Mecoptera						
	Meropeidae	earwigflies	x			C09b
	Panorpidae	common scorpionflies	x			Ca31, C07b, C08g, C13d, S90a, Ca28, Ca31, Ca55, C09b
	Bittacidae	hangingflies	x	x		
Diptera						
	Tipulidae	crane flies	x	x	x	C08a, C08j, C09h, C10, C21a, C25a, Ha10, M49, S78, S90a, S94, Wi77b
	Ptychopteridae	phantom crane flies	x		x	C10, Ha10
	Culicidae	mosquitoes		x		C21a, S90a

Table 1. (Continued.) Systematic list of insect families known from three Paleogene faunas. Abbreviations p. 19.

Order	Family	Common Name	Florissant	Green River	British Columbia	References
	Chironomidae	midges	x	x		C10, S78, S90a,
	Scatopsidae	minute black scavenger flies	x			M49
	Bibionidae	March flies	x	x	x	C09d, C11, C14b, C16, C17a, C17b, C21a, C25a, Ha10, H60, J39 M49, Ri59, S90a, Wi77b
	Cecidomyiidae	gall gnats	x	x		C08a, S90a
	Sciaridae	dark-winged fungus gnats	x	x	x	C16, M49, S90a Wi 77b
	Mycetophilidae	fungus gnats	x	x	x	C06d, C09a, C11, C14b, C14f, C21a, C25a, M49, S78, S90a, Wi77b
	Rhagionidae	snipe flies	x			C08d, C09a, C09g, C11, C13d, C14e, M49
	Tabanidae	horse and deer flies	x	x?		C09g, C16, M46, MC75
	Stratiomyidae	soldier flies	x	x		C10, C11, C13d, C17d, J37, J39, S90a
	Nemestrinidae	tangle-veined flies	x			Be47, BeCa36, C08k, C08o, C08p, C10 C14a, M49
	Acroceridae	small-headed flies		x		S90a
	Therevidae	stiletto flies	x			C09c, C09g, C16, C21a, M49
	Asilidae	robber flies	x	x		C08d, C09f, C09g, C10, C11, C13b, C13d, C14a, C14b, C14e, C17b, C21a, H57, J39, M46, M49, S78
	Mydidae	mydas flies	x			C13a
	Bombyliidae	bee flies	x			C09a, C09c, C09g, C10, C11, C14a, C14b, C14e, C16, C17a, C17d, H73, M46, M49
	Empididae	dance flies	x	x	x	C14b, C15, C16, C17a, C21a, Ha10, J37, J39, M49, Wi77b
	Dolichopodidae	long-legged flies		x		S78, S90a
	Platypezidae	flat-footed flies	x	x		C09a, C11, S90a
	Phoridae	humpbacked flies	x			B08a, C13c, M49
	Syrphidae	hover or flower flies	x	x	x	C09a, C09a, C09f, C09g, C14a, C16, C21a, C24, C25a, CL31, H45, H49, H60, J32, M49, S78, S90a, Wi77b
	Conopidae	thick-headed flies		x		S90a
	Otitidae	picture-winged flies	x			C16, C17a, M49
	Tephritidae	fruit flies		x		C25a
	Sepsidae	black scavenger flies	x			M49
	Sciomyzidae	marsh flies	x	x		C09c, S78, S90a
	Lauxaniidae	lauxaniid flies	x			M49
	Heleomyzidae	helomyzid flies	x	x		C14b, M49, S90a
	Piophilidae	skipper flies	x			M49
	Agromyzidae	leaf miner flies	x			M49

Table 1. (Continued.) Systematic list of insect families known from three Paleogene faunas. Abbreviations p. 19.

Order	Family	Common Name	Florissant	Green River	British Columbia	References
Trichoptera	Anthomyiidae	anthomyiid flies	x	x		C13f, C17a, C21a
	Eophlebomyiidae					
	and Glossinidae	tsetse flies	x	x		C17d, C25a, C25c
	Muscidae	muscid flies	x	x		C07b, C07h, C08a, C09j, S90a
	Tachinidae	tachinid flies		x		S78, S90a
	Oestridae	warble and bot flies	x	x		C16, S92a
	Hydropsychidae	net-spinning caddisflies	x	x	x	Wi77b
						C07a, C09b, C09g, C10, S90a
	Hydroptilidae	micro-caddisflies		x		C21a
	Limnephilidae	northern caddisflies	x	x		C07a, C10, C21a, S90a
Lepidoptera	Phryganeidae	large caddisflies	x			C07a, C14a, S90a
	Leptoceridae	long-horned caddisflies	x			S90a
	Odontoceridae	odontocerids	x			C09b
	Sericostomatidae	sericostomatids		x		Br24, Br74
	Cossidae	carpenter and leopard moths	x			C26a
	Tortricidae	tortricid moths	x			C07g, C16, C22b
	Tineidae	clothes moths etc.	x			S90a
	Yponomeutidae	ermine moths		x		C33, CL31, F31
	Oecophoridae	oecophorid moths	x			C13d
	Ethmiidae	ethmiid moths	x			C22b
Hymenoptera	Thyrididae	window-winged moths		x		C33
	Papilionidae	swallowtaits	x			S87
	Pieridae	whites, sulphurs and orange-tips	x			C13d, C22b
	Nymphalidae	brush-footed butterflies	x			C08a, C22b, S87, S92a
	Libytheidae	snout butterflies	x			C22b
	Geometridae	measuring worms	x			C22b
	Saturniidae	giant silkworm moths	x			C22b
	Orussidae	parasitic wood wasps	x			B06
	Siricidae	horntails	x			B08b
	Tenthredinidae	common sawflies	x	x	x	B08b, C06b, C07a, C07b, C08g, C09f, C10, C11, C14b, C14d, C16, C17a, C17b, C22a, Ri68, R08b, R08c, S92a
	Blasticotomidae	blasticotomid sawflies	x			Ben42, B08b, R08b, C13d
	Xyelidae	xyelid sawflies	x			
	Pamphilidae	web-spinning and leaf-rolling sawflies	x			B08b, C13d, R08b, R08c
	Cephidae	stem sawflies	x			C14a
	Stephanidae	stephanids	x			B10a
	Ichneumonidae	ichneumonid wasps	x	x	x	B06, B10a, B10b, C06d, C19, C21a, C24, C41, CL31, Ha10, S90a, Wi77b
	Braconidae	braconid wasps	x	x	x	B06, B10a, B10b, S78, S90a, Wi77b
	Evanliidae	ensign wasps	x			B10a, B10b, C16
	Proctotrupidae	proctotrupids	x			B10a, B10b
	Scelionidae	scelionid wasps	x			C14b

Table 1. (Continued.) Systematic list of insect families known from three Paleogene faunas. Abbreviations p. 19.

Order	Family	Common Name	Florissant	Green River	British Columbia	References
	Diapriidae	diapriid wasps	x			B06, B10a, B10b, C13d
	Figitidae	figitids	x			B10a
	Cynipidae	gall wasps	x			B10a, B10b
	Agaonidae	fig wasps	x			B10a, B10b
	Mymaridae	fairy flies	x			B10b
	Chalcididae	chalcidid wasps	x	x		B10a, C07a, S90a
	Eurytomidae	seed chalcids	x			B10a, B10b
	Torymidae	torymids	x			B10a, B10b
	Pteromalidae	pteromalids	x			B10a, B10b
	Chrysididae	cuckoo wasps	x			C07a, R09
	Bethylidae	bethylid wasps	x			B06, B10a, B10b
	Pompilidae	spider wasps	x			C06d, C08j, C14a, C41
	Scoliidae	scoliid wasps	x			C07j
	Tiphidae	tiphiid wasps	x			C10, C13b
	Vespidae	vespid wasps	x		x	C06d, C07a, C11, C14b, C23c, Wi77b
	Eumenidae	potter wasps	x			C09f, C13d, C14b
	Sphecidae	sphecid wasps	x	x		C06d, C07a, R08a, R08d, R09, S90a
	Halictidae	halictid bees	x			C06d, ZM76
	Andrenidae	andrenid bees	x			C06d, C081, C11, C14b, ZM76
	Melittidae	melittid bees	x			ZM76
	Megachilidae	leaf-cutting bees	x			C06d, C08b, C08f, C081, C17a, C23c, ZM76
	Anthophoridae	digger bees	x	x?		Bn34, Bn35, C06c, C081, ZM76
	Apidae	honey bees	x			C081, C08t, ZM76
	Formicidae	ants	x	x	x	Ca47, C06c, C21c, C23a, C41, S78, S90a

Insects recorded from the fauna are: Odonata - Libellulidae; Hemiptera - Pentatomidae; Homoptera - Aphididae; Neuroptera - Hemerobiidae; Coleoptera - Nitidulidae; Diptera - Chironomidae, Mycetophilidae, Dolichopodidae, Otitidae, Sciomyzidae, Heleomyzidae, Pallopteridae, Lonchaeidae, Anthomyzidae; Hymenoptera -Ichneumonidae, Braconidae, Formicidae. According to Scudder (1890a) most specimens are Diptera and Hymenoptera.

The flora records a humid, warm temperate to near subtropical climate (Piel, 1971). The Oligocene paleolatitude of the Quesnel area was presumably intermediate between its Eocene latitude of about 60° N and its present latitude of 53° N.

CONCLUSIONS

North American Paleogene insect faunas are known from a large number of localities extending from British Columbia in the north-west to Colorado in the south-east. Paleocene faunas are few and are confined to the Great Plains. Eocene and Oligocene faunas are numerous and occur in the intermontane basins of the Cordillera. The faunas occur predominantly in fine-grained lacustrine sediments in association with compression fossils of leaves and fishes. Inferred paleoclimates vary from temperate to tropical, based mostly on paleobotanical evidence. Latitudes ranged from about 43° N to more than 60° N during deposition of the faunas. To date only limited use has been made of the insects for paleoenvironmental reconstruction.

More than 200 families of insects have been recognized to date. Of these 90 are known from Eocene formations and about 190 from Oligocene formations. Only a few families are recorded from the Paleocene. In numbers of individuals the faunas are dominated by Coleoptera, Diptera, and Hymenoptera, with Bibionidae of the genus *Plecia* and parasitic Hymenoptera such as Ichneumonidae being especially abundant.

ACKNOWLEDGEMENTS

I thank C. Bartlett, R. Campbell, H. Tyson, and C. Wilson for their assistance in this study. I also thank Dr. G. Middleton for helpful comments on Green River paleoecology, and D. Wighton and P. Mitchell for unpublished information on Paskapoo Formation insects. A Lindoe assisted me during collecting trips to many of the localities referred to in the text. This research was supported by the National Research Council of Canada operating grant A9180 to the author.

REFERENCES

- Axelrod, D.I. 1966. The Eocene Copper Basin flora of northeastern Nevada. University of California Publications, Geological Sciences 59: 1-123.
- Baer, J.L. 1969. Paleoecology of cyclic sediments of the Lower Green River Formation, central Utah. Brigham Young University Geological Studies 16: 3-95.
- Becker, H.F. 1960. The Tertiary Mormon Creek flora from the Upper Ruby River Basin in southwestern Montana. *Palaeontographica*, Abt. A 107: 83-126.
- Becker, H.F. 1961. Oligocene plants from the Upper Ruby River Basin, Southwestern Montana. Geological Society of America Memoir 82: 1-127.
- Becker, H.F. 1965. Flowers, insects, and evolution. *Natural History* 74: 38-45.
- Becker, H.F. 1966. Additions to and revision of the Oligocene Ruby Paper Shale flora of southwestern Montana. *Contributions from the Museum of Paleontology, the University of Michigan* 20: 89-119.
- Benson, R.B. 1942. Blasticotomidae in the Miocene of Florissant, Colorado (Hymenoptera Symphyta), *Psyche* 49: 47-48.
- Bequaert, J.C. 1947. Catalogue of Recent and fossil Nemestrinidae of America north of Mexico. *Psyche* 54: 194-207.
- Bequaert, J.E., and F.M. Carpenter. 1936. The Nemestrinidae of the Miocene of Florissant, Colorado and their relations to the Recent fauna. *Journal of Paleontology* 10: 395-409.
- Berry, E.W. 1929. A revision of the flora of the Latah Formation. United States Geological Survey, Professional Paper 154-H: 225-265.
- Bradley, W.H. 1924. Fossil caddisfly cases from the Green River Formation of Wyoming. *American Journal of Science* 7: 310-312.
- Bradley, W.H. 1948. Limnology and the Eocene lakes of the Rocky Mountain Region. *Bulletin of the Geological Society of America* 59: 635-648.
- Bradley, W.H. 1974. *Oocardium* tufa from the Eocene Green River Formation of Wyoming. *Journal of Paleontology* 48: 1289-1294.
- Brown, R.W. 1934. *Celliforma spirifer*, the fossil larval chambers of mining bees. *Journal of the Washington Academy of Sciences* 24: 532-539.
- Brown, R.W. 1935. Further notes on fossil larval chambers of mining bees. *Journal of the Washington Academy of Sciences* 25: 526-528.
- Brown, R.W. 1937. Additions to some fossil floras of the western United States. United States Geological Survey, Professional Paper 186-J: 163-206.

- Brown, R.W. 1957. Cockroach egg case from the Eocene of Wyoming. *Journal of the Washington Academy of Sciences* 47: 340–342.
- Brown, R.W. 1962. Paleocene flora of the Rocky Mountains and Great Plains. United States Geological Survey, Professional Paper 375: 1–119.
- Brues, C.T. 1906. Fossil parasitic and phytophagous Hymenoptera from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 22: 491–498.
- Brues, C.T. 1908a. Two fossil Phoridae from the Miocene shales of Florissant, Colorado. *Bulletin of the American Museum of Natural History* 24: 273–275.
- Brues, C.T. 1908b. New phytophagous Hymenoptera from the Tertiary of Florissant, Colorado. *Bulletin of the Museum of Comparative Zoology* 51: 257–276.
- Brues, C.T. 1908c. A fossil Cercopidae. *Bulletin of the Wisconsin Natural History Society*, 6: 35–38.
- Brues, C.T. 1910a. The parasitic Hymenoptera of the Tertiary of Florissant, Colorado. *Bulletin of the Museum of Comparative Zoology* 54: 1–123.
- Brues, C.T. 1910b. Some notes on the geological history of the parasitic Hymenoptera. *Journal of the New York Entomological Society* 28: 1–23.
- Brues, C.T., L.A. Melander, and F.M. Carpenter. 1954. Classification of insects. Keys to the living and extinct families of insects and to the living families of other terrestrial arthropods. *Bulletin of the Museum of Comparative Zoology* 108: 1–917.
- Buchheim, H.P., and R.C. Surdam. 1977. Fossil catfish and the depositional environment of the Green River Formation, Wyoming. *Geology* 5: 196–198.
- Carpenter, F.M. 1928. A scorpion fly from the Green River Eocene. *Annals of the Carnegie Museum* 18: 241–249.
- Carpenter, F.M. 1931. The affinities of *Holcorpa maculosa* Scudder and other Tertiary Mecoptera with descriptions of the new genera. *Journal of the New York Entomological Society* 39: 405–414.
- Carpenter, F.M. 1935. Tertiary insects of the family Chrysopidae. *Journal of Palaeontology* 9: 259–271.
- Carpenter, F.M. 1936. Revision of the Nearctic Raphidiodea (Recent and fossil). *Proceedings of the American Academy of Arts and Sciences* 71: 88–157.
- Carpenter, F.M. 1947. [List of fossil insects] In H.M.A. Rice. *Geology and Mineral deposits of the Princeton map-area, British Columbia*. Geological Survey of Canada Memoir 243: 31.
- Carpenter, F.M. 1955. An Eocene *Bittacus* (Mecoptera). *Psyche* 62: 39–41.
- Carpenter, F.M., T.E. Snyder, C.P. Alexander, M.T. James, and F.M. Hull. 1938. Fossil insects from the Creede Formation, Colorado. *Psyche* 45: 105–119.
- Cockerell, T.D.A. 1906a. A fossil cicada from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 22: 457–458.
- Cockerell, T.D.A. 1906b. Fossil saw-flies from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 22: 499–501.
- Cockerell, T.D.A. 1906c. A new fossil ant. *Entomological News* 17: 27–28.
- Cockerell, T.D.A. 1906d. Fossil Hymenoptera from Florissant, Colorado. *Bulletin of the Museum of Comparative Zoology* 50: 3–58.
- Cockerell, T.D.A. 1907a. Some fossil arthropods from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 23: 605–616.
- Cockerell, T.D.A. 1907b. Some Old-World types of insects in the Miocene of Colorado. *Science* 26: 446–447.
- Cockerell, T.D.A. 1907c. An enumeration of the localities in the Florissant Basin from which fossils were obtained in 1906. *Bulletin of the American Museum of Natural History* 23: 127–133.

- Cockerell, T.D.A. 1907d. Fossil dragonflies from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 23: 133–139.
- Cockerell, T.D.A. 1907e. A new fly (Family Mycetophilidae) from the Green River Beds. *American Journal of Science*, 23: 285–287.
- Cockerell, T.D.A. 1907f. A fossil caterpillar. *Canadian Entomologist* 39: 187–189.
- Cockerell, T.D.A. 1907g. A fossil tortricid moth. *Canadian Entomologist* 39: 416.
- Cockerell, T.D.A. 1907h. A fossil tse-tse fly in Colorado. *Nature* 76: 414.
- Cockerell, T.D.A. 1907i. A fossil butterfly of the genus *Chlorippe*. *Canadian Entomologist* 39: 361–363.
- Cockerell, T.D.A. 1907j. A Miocene wasp. *Nature* 77: 80.
- Cockerell, T.D.A. 1908a. Fossil insects from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 24: 59–69.
- Cockerell, T.D.A. 1908b. A fossil leaf-cutting bee. *Canadian Entomologist* 40: 31.
- Cockerell, T.D.A. 1908c. Fossil Chrysopidae. *Canadian Entomologist* 40: 90.
- Cockerell, T.D.A. 1908d. Two fossil Diptera. *Canadian Entomologist* 40: 173–175.
- Cockerell, T.D.A. 1908e. Fossil Osmylidae (Neuroptera) in America. *Canadian Entomologist* 40: 341–342.
- Cockerell, T.D.A. 1908f. The first American fossil mantis. *Canadian Entomologist* 40: 343–344.
- Cockerell, T.D.A. 1908g. The fossil sawfly *Perga coloradensis*. *Science* 27: 113–114.
- Cockerell, T.D.A. 1908h. Descriptions of Tertiary insects. *American Journal of Science* 25: 51–53.
- Cockerell, T.D.A. 1908i. Descriptions of Tertiary insects. *American Journal of Science* 26: 69–75.
- Cockerell, T.D.A. 1908j. Descriptions of Tertiary insects. *American Journal of Science* 25: 227–232.
- Cockerell, T.D.A. 1908k. Descriptions of Tertiary insects. *American Journal of Science* 25: 309–313.
- Cockerell, T.D.A. 1908l. Descriptions and records of bees. *Annals and Magazine of Natural History* 2: 323–335.
- Cockerell, T.D.A. 1908m. A fossil orthopterous insect with media and cubitus fusing. *Entomological News* 19: 126–128.
- Cockerell, T.D.A. 1908n. A fossil Aphididae from Florissant, Colorado. *Nature* 78: 318–319.
- Cockerell, T.D.A. 1908o. Dipterous family Nemestrinidae. *Transactions of the American Entomological Society* 34: 247–253.
- Cockerell, T.D.A. 1908p. Another fossil nemestrinid fly. *Transactions of the American Entomological Society* 34: 247–254.
- Cockerell, T.D.A. 1908q. A dragon-fly puzzle and its solution. *Entomological News* 19: 455–459.
- Cockerell, T.D.A. 1908r. Florissant, a Miocene Pompeii. *Popular Science Monthly* 73: 112–126.
- Cockerell, T.D.A. 1908s. A fossil Cercopidae (Homoptera). *Bulletin of the Wisconsin Natural History Society* 6: 35–38.
- Cockerell, T.D.A. 1908t. Some results of the Florissant expedition of 1908. *American Naturalist* 42: 569–581.
- Cockerell, T.D.A. 1909a. Descriptions of the Tertiary insects. Some new Diptera. *American Journal of Science* 27: 53–59.
- Cockerell, T.D.A. 1909a. Descriptions of Tertiary insects. Some new Diptera. *American* 381–387.
- Cockerell, T.D.A. 1909c. Fossil Diptera from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 26: 9–12.

- Cockerell, T.D.A. 1909d. Fossil insects from Colorado. *The Entomologist* 42: 170–174.
- Cockerell, T.D.A. 1909e. Two fossil Chrysopidae. *Canadian Entomologist* 41: 218–219.
- Cockerell, T.D.A. 1909f. New fossil insects from Florissant, Colorado. *Annals of the Entomological Society of America* 1: 251–256.
- Cockerell, T.D.A. 1909g. Fossil insects from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 26: 67–76.
- Cockerell, T.D.A. 1909h. Descriptions of Tertiary insects. *American Journal of Science* 28: 283–287.
- Cockerell, T.D.A. 1909i. Eocene fossils from Green River, Wyoming. *American Journal of Science* 28: 447–448.
- Cockerell, T.D.A. 1909j. Another fossil tsetse fly. *Nature* 80: 128.
- Cockerell, T.D.A. 1910. Fossil insects and a crustacean from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 28: 275–288.
- Cockerell, T.D.A. 1911. Fossil insects from Florissant, Colorado. *Bulletin of the American Museum of Natural History* 30: 71–82.
- Cockerell, T.D.A. 1912. A fossil *Raphidia*. *Entomological News* 23: 215–216.
- Cockerell, T.D.A. 1913a. The first fossil mydaid fly. *The Entomologist* 46: 207–208.
- Cockerell, T.D.A. 1913b. A fossil asilid fly from Colorado. *The Entomologist* 46: 213–214.
- Cockerell, T.D.A. 1913c. Two fossil insects from Florissant with a discussion of the venation of the aeshnine dragonflies. *Proceedings of the United States National Museum* 45: 577–583.
- Cockerell, T.D.A. 1913d. The fauna of the Florissant Shales. *American Journal of Science* 186: 498–500.
- Cockerell, T.D.A. 1913e. The genera *Prototermes* and *Hodotermes*. *Entomological News* 24: 6–8.
- Cockerell, T.D.A. 1913f. The first fossil anthomyid fly from Florissant. *Entomological News* 24: 295–296.
- Cockerell, T.D.A. 1914a. New and little-known insects from the Miocene of Florissant, Colorado. *Journal of Geology* 22: 714–724.
- Cockerell, T.D.A. 1914b. Miocene fossil insects. *Proceedings of the Academy of Natural Science of Philadelphia* 66: 634–648.
- Cockerell, T.D.A. 1914c. The fossil and Recent Bomyliidae compared. *Bulletin of the American Museum of Natural History* 33: 229–236.
- Cockerell, T.D.A. 1914d. A new fossil sawfly from Florissant, Colorado. *The Entomologist* 46: 32.
- Cockerell, T.D.A. 1914e. Three Diptera from the Miocene of Colorado. *Canadian Entomologist* 46: 101–102.
- Cockerell, T.D.A. 1914f. A fossil fungus-gnat. *Canadian Entomologist* 46: 159.
- Cockerell, T.D.A. 1915. Two Diptera of the genus *Rhamphomyia* from Colorado. *Canadian Entomologist* 47: 123–124.
- Cockerell, T.D.A. 1916. Some American fossil insects. *Proceedings of the United States National Museum* 51: 89–106.
- Cockerell, T.D.A. 1917a. New Tertiary insects. *Proceedings of the United States National Museum* 52: 373–384.
- Cockerell, T.D.A. 1917b. Some fossil insects from Florissant, Colorado. *Proceedings of the United States National Museum* 53: 389–393.
- Cockerell, T.D.A. 1917c. Fossil insects. *Annals of the Entomological Society of America* 10: 1–18.
- Cockerell, T.D.A. 1917d. A fossil tse-tse fly and other Diptera from Florissant. *Proceedings of the Biological Society of Washington* 30: 19–22.

- Cockerell, T.D.A. 1919. Some fossil parasitic Hymenoptera. *American Journal of Science* 47: 376–380.
- Cockerell, T.D.A. 1921a. Eocene insects from the Rocky Mountains. *Proceedings of the United States National Museum* 57: 233–260.
- Cockerell, T.D.A. 1921b. Some Eocene insects from Colorado and Wyoming. *Proceedings of the United States National Museum* 59: 29–38.
- Cockerell, T.D.A. 1921c. Some Eocene insects of the Family Fulgoridae. *Proceedings of the United States National Museum* 59: 455–457.
- Cockerell, T.D.A. 1922a. The fossil sawflies of Florissant, Colorado. *The Entomologist* 55: 49–53.
- Cockerell, T.D.A. 1922b. A fossil moth from Florissant, Colorado. *American Museum Novitates*, 34: 1–2.
- Cockerell, T.D.A. 1923a. The earliest known ponerine ant. *The Entomologist* 56: 51–52.
- Cockerell, T.D.A. 1923b. A new genus of mayflies from the Miocene of Florissant, Colorado. *Psyche* 30: 170–172.
- Cockerell, T.D.A. 1923c. Two fossil Hymenoptera from Florissant (Vespidae, Megachilidae). *Entomological News* 34: 270–271.
- Cockerell, T.D.A. 1924. Fossil ichneumons believed to have been parasitic on sawflies. *The Entomologist* 57: 9–11.
- Cockerell, T.D.A. 1925a. Fossil insects in the United States National Museum. *Proceedings of the United States National Museum* 64: 1–15.
- Cockerell, T.D.A. 1925b. A new fossil dragonfly from Florissant. *The Entomologist* 58: 205–206.
- Cockerell, T.D.A. 1925c. The Eocene fossil fly *Eophlebomyia*. *Psyche* 32: 229–230.
- Cockerell, T.D.A. 1926a. A new fossil moth from Florissant. *Psyche* 33: 16–17.
- Cockerell, T.D.A. 1926b. A fossil orthopterous insect formerly referred to Mecoptera. *Proceedings of the Entomological Society of Washington* 28: 142.
- Cockerell, T.D.A. 1926c. Some Tertiary fossil insects. *Annals and Magazine of Natural History*, 18: 313–324.
- Cockerell, T.D.A. 1928. A remarkable new dragonfly from the Eocene (Odonata). *Entomological News* 39: 297–301.
- Cockerell, T.D.A. 1933. A second moth from the Colorado Eocene. *The American Naturalist* 67: 479–480.
- Cockerell, T.D.A. 1940. A dragonfly from the Eocene of Colorado (Odonata: Agrionidae). *Entomological News* 51: 103–107.
- Cockerell, T.D.A. 1941. Some Tertiary insects (Hymenoptera) from Colorado. *American Journal of Science* 239: 354–356.
- Cockerell, T.D.A., and C. Custer. 1925. A new fossil *Inocellia* from Florissant. *Entomologist* 58: 295–297.
- Cockerell, T.D.A. and N. LeVeque. 1931. The antiquity of insect structures. *American Naturalist* 65: 351–359.
- Cooper, K.W. 1941. *Davisia bearcreekensis* Cooper, a new cicada from the Paleocene, with a brief review of the fossil Cicadidae. *American Journal of Science* 239: 286–304.
- Dorr, J.A., Jr., and W.H. Wheeler. 1964. Cenozoic paleontology, stratigraphy, and reconnaissance geology of the Upper Ruby River Basin, southwestern Montana. *Contributions from the Museum of Paleontology, The University of Michigan* 13: 297–339.
- Emerson, A.E. 1933. A revision of the genera of fossil and recent Termopsinae (Isoptera). *University of California Publications in Entomology* 6: 165–196.
- Emerson, A.E. 1965. A review of the Mastotermitidae (Isoptera) including a new fossil genus from Brazil. *American Museum Novitates* 2236: 1–46.

- Emerson, A.E. 1968. A revision of the fossil genus *Almeriella* (Isoptera, Hodotermitidae, Hodotermitinae). *American Museum Novitates*, 2332: 1–22.
- Emerson, A.E. 1969. A revision of the Tertiary fossil species of *Kalotermitidae* (Isoptera). *American Museum Novitates* 2359: 1–53.
- Eugster, H.P., and L.A. Hardie. 1975. Sedimentation in an ancient playa-lake complex: the Wilkins Peak Member of the Green River Formation of Wyoming. *Geological Society of America, Bulletin* 86: 319–334.
- Eugster, H.P., and R.C. Surdam. 1973. Depositional environment of the Green River Formation of Wyoming: A preliminary report. *Geological Society of America, Bulletin* 84: 115–120.
- Forbes, W.T.M. 1931. The oldest moth. *American Naturalist* 65: 479–480.
- Foster, R.J. 1960. Tertiary geology of a portion of the Central Cascade Mountains, Washington. *Bulletin of the Geological Society of America* 71: 99–126.
- Gazin, C.L. 1935. A marsupial from the Florissant beds (Tertiary) of Colorado. *Journal of Paleontology* 9: 57–62.
- Hail, W.J., Jr. 1965. Geology of Northwestern North Park, Colorado. *United States Geological Survey, Bulletin* 1188: 1–133.
- Handlirsch, A. 1910. Contributions to Canadian Palaeontology. Vol. II. Part III. Canadian fossil insects. 5. Insects from the Tertiary lake deposits of the Southern Interior of British Columbia collected by Mr. Lawrence Lambe, in 1906. *Geological Survey of Canada Memoir* 12: 93–129.
- Hull, F.M. 1945. A revisional study of the fossil Syrphidae. *Bulletin of the Museum of Comparative Zoology* 95: 250–355.
- Hull, F.M. 1949. The morphology and interrelationship of the genera of syrphid flies, Recent and fossil. *Transactions of the Zoological Society of London* 26: 257–408.
- Hull, F.M. 1957. Tertiary flies from Colorado and Baltic Amber. *Psyche* 64: 37–45.
- Hull, F.M. 1960. A new genus and four new species of fossil Diptera from Montana and Colorado. *Contributions from the Museum of Palaeontology of the University of Michigan* 15: 269–279.
- Hull, F.M. 1962. Robber flies of the world: genera of the family Asilidae. *Bulletin of the United States National Museum* 224: 1–907.
- Hull, F.M. 1973. Bee flies of the world: the genera of the family Bombyliidae. *Bulletin of the United States National Museum* 286: 1–687.
- James, M.T. 1932. A new Eocene syrphid from Colorado (Diptera). *Canadian Entomologist* 64: 264.
- James, M.T. 1937. A preliminary review of certain families of Diptera from the Florissant Miocene Beds. *Journal of Palaeontology* 11: 241–247.
- James, M.T. 1939. A preliminary review of certain families of Diptera from the Florissant Miocene beds. II. *Journal of Paleontology* 13: 42–48.
- Jurdy, D.M., and R. Van Der Voo. 1975. True polar wander since the Early Cretaceous. *Science* 188: 1193–1196.
- Leopold, E.B., and H.D. MacGinitie. 1972. Development and affinities of Tertiary floras in the Rocky Mountains. In Graham, A., (Ed.) *Floristics and paleofloristics of Asia and Eastern North America*. Elsevier, New York. 147–200.
- Lewis, S.E. 1971a. A new species of fossil Diptera (Diopsidae) from the Ruby River Basin (Oligocene) of Montana. *Annals of the Entomological Society of America* 64: 959–960.
- Lewis, S.E. 1971b. Three new species of fossil Diptera (Bibionidae) from the Ruby River Basin (Oligocene) of Southwestern Montana. *Annals of the Entomological Society of America* 64: 1464–1466.

- Lewis, S.E. 1972. A new species of fossil bee fly (Diptera: Bombyliidae) from the Ruby River Basin (Oligocene) of Southwestern Montana. *Annals of the Entomological Society of America* 65: 1421.
- Lewis, S.E. 1975. A new species of fossil bombyliid (Diptera: Bombyliidae) from the Ruby River Basin (Oligocene) of Southwestern Montana. *Journal of Paleontology* 49: 422–429.
- Lewis, S.E. 1976. Lepidopterous feeding damage of live oak leaf (*Quercus convexa* Lesquereux) from the Ruby River Basin (Oligocene) of Southwestern Montana. *Journal of Paleontology*, 50: 345–346.
- McGrew, P.O. 1975. Taphonomy of Eocene fish from Fossil Basin, Wyoming. *Fieldiana Geology* 33: 257–270.
- McGrew, P.O., and M. Casilliano. 1975. The geological history of Fossil Butte National Monument and Fossil Basin. United States National Park Service, Occasional Bulletin 3: 1–37.
- McLeroy, C.A., and R.Y. Anderson. 1966. Laminations of the Oligocene Florissant Lake Deposits, Colorado. *Geological Society of America, Bulletin* 77: 605–618.
- Melander, A.L. 1946. Some fossil Diptera from Florissant, Colorado. *Psyche* 53: 43–49.
- Melander, A.L. 1949. A report on some Miocene Diptera from Florissant, Colorado. *American Museum Novitates* 1407: 1–55.
- Piel, K.M. 1971. Palynology of Oligocene sediments from central British Columbia. *Canadian Journal of Botany* 49: 1885–1920.
- Rice, H.M.A. 1959. Fossil Bibionidae (Diptera) from British Columbia. *Geological Survey of Canada Bulletin* 55: 1–24.
- Rice, H.M.A. 1968. Two Tertiary sawflies (Hymenoptera Tenthredinidae) from British Columbia. *Geological Survey of Canada Paper* 67–59: 1–21.
- Roehler, H.W. 1972. A review of Eocene stratigraphy in the Washakie Basin, Wyoming. Guidebook, Field Conference on Tertiary Biostratigraphy of Southern and Western Wyoming 3–19.
- Rohwer, S.A. 1908a. A fossil larrid wasp. *Bulletin of the American Museum of Natural History* 24: 519–520.
- Rohwer, S.A. 1908b. On the Tenthredinoidea of the Florissant Shales. *Bulletin of the American Museum of Natural History* 24: 521–530.
- Rohwer, S.A. 1908c. On the Tenthredinoidea of the expedition of 1908 to Florissant, Colorado. *Bulletin of the American Museum of Natural History* 24: 591–595.
- Rohwer, S.A. 1908d. A fossil mellinid wasp. *Bulletin of the American Museum of Natural History* 24: 597.
- Rohwer, S.A. 1909. Three new fossil insects from Florissant, Colorado. *American Journal of Science* 28: 533–536.
- Rouse, G.E., W.S. Hopkins, and K.M. Piel. 1971. Palynology of some Late Cretaceous and Early Tertiary deposits in British Columbia and adjacent Alberta. *Geological Society of America, Special Paper* 127: 213–246.
- Schaeffer, B., and M. Mangus. 1965. Fossil lakes from the Eocene. *Natural History* 74: 10–21.
- Scudder, S.H. 1878. The fossil insects of the Green River Shales. *United States Geological Survey, Bulletin* 4: 747–776.
- Scudder, S.H. 1882. The Tertiary lake-basin at Florissant, Colorado, between South and Hayden Parks. *United States Geological Survey, Bulletin* 6: 279–300.
- Scudder, S.H. 1886. Systematic review of our present knowledge of fossil insects. *United States Geological Survey, Bulletin* 31: 1–128.
- Scudder, S.H. 1887. The fossil butterflies of Florissant. *United States Geological Survey 8th Annual Report, Part I*: 433–474.
- Scudder, S.H. 1890a. The Tertiary insects of North America. *Report of the United States Geological Survey of the Territories* 13: 1–662.

- Scudder, S.H. 1890b. Physiognomy of the American Tertiary Hemiptera. *Proceedings of the Boston Society of Natural History* 24: 562–579.
- Scudder, S.H. 1890c. The fossil insect localities in the Rocky Mountain Region. *Psyche* 5: 363.
- Scudder, S.H. 1890d. A classed and annotated bibliography of fossil insects. United States Geological Survey, Bulletin 69: 1–101.
- Scudder, S.H. 1892a. Some insects of special interest from Florissant, Colorado and other points in the Tertiaries of Colorado and Utah. United States Geological Survey, Bulletin 93: 3–35.
- Scudder, S.H. 1892b. The Tertiary Rhyncophora of North America. *Proceedings of the Boston Society of Natural History* 25: 370–386.
- Scudder, S.H. 1893. Tertiary rhyncophorous Coleoptera of the United States. *Monographs of the United States Geological Survey* 21: 1–206.
- Scudder, S.H. 1894. Tertiary Tipulidae: with special reference to those of Florissant, Colorado. *Proceedings of the American Philosophical Society*, 32: 163–245.
- Scudder, S.H. 1895. Canadian fossil insects, myriapods and arachnids. 1. The Tertiary Hemiptera of British Columbia. 2. The coleoptera hitherto found fossil in Canada. *Geological Survey of Canada, Contributions to Canadian Palaeontology* 2: 5–36.
- Scudder, S.H. 1900. Adephagous and clavicorn Coleoptera from the Tertiary deposits at Florissant, Colorado. *Monographs of the United States Geological Survey* 40: 1–148.
- Snyder, T.E. 1925. Notes on fossil termites with particular reference to Florissant, Colorado. *Proceedings of the Biological Society of Washington* 38: 149–166.
- Snyder, T.E. 1950. The fossil termites of the United States and their living relatives. *Proceedings of the Entomological Society of Washington* 52: 190–193.
- Surdam, R.C., and C.A. Wolfbauer. 1975. Green River Formation, Wyoming: a playa-lake complex. *Geological Society of America, Bulletin* 86: 335–345.
- Wickham, H.F. 1908. New fossil Elateridae from Florissant. *American Journal of Science* 26: 77–79.
- Wickham, H.F. 1909. New fossil Coleoptera from Florissant. *American Journal of Science* 28: 126–130.
- Wickham, H.F. 1911. Fossil Coleoptera from Florissant, with descriptions of several new species. *Bulletin of the American Museum of Natural History* 30: 53–69.
- Wickham, H.F. 1913. Fossil Coleoptera from Florissant in the United States National Museum. *Proceedings of the United States National Museum* 45: 283–301.
- Wickham, H.F. 1914a. Twenty new Coleoptera from the Florissant Shales. *Transactions of the American Entomological Society* 40: 257–271.
- Wickham, H.F. 1914b. New Miocene Coleoptera from Florissant. *Bulletin of the Museum of Comparative Zoology* 58: 423–471.
- Wickham, H.F. 1916. The fossil Elateridae of Florissant. *Bulletin of the Museum of Comparative Zoology* 12: 493–527.
- Wickham, H.F. 1917. New species of fossil beetles from Florissant, Colorado. *Proceedings of the United States National Museum* 52: 463–471.
- Wickham, H.F. 1920. Catalogue of the North American Coleoptera described as fossils, pp. 349–365, *In* Leng, C.W. *Catalogue of the Coleoptera of America north of Mexico*. J.D. Sherman, Mount Vernon, N.Y.
- Wilson, M.V.H. 1977a. Paleocology of Eocene lacustrine varves at Horsefly, British Columbia. *Canadian Journal of Earth Sciences* 14: 953–962.
- Wilson, M.V.H. 1977b. New records of insect families from the freshwater Middle Eocene of British Columbia. *Canadian Journal of Earth Sciences* 14: 1139–1155.

- Wilson, M.V.H. 1977c. Middle Eocene freshwater fishes of British Columbia. Life Science Contributions, Royal Ontario Museum 113: 1-61.
- Wilson, M.V.H. In press. *Eochiodon woodruffi* n. sp. (Teleostei, Hiodontidae), from the Middle Eocene Klondike Mountain Formation near Republic, Washington. Canadian Journal of Earth Sciences.
- Zeuner, F.E. and F.J. Manning. 1976. A monograph of fossil bees (Hymenoptera: Apoidea). Bulletin of the British Museum (Natural History) **Geology** 27: 149-268.
- Zuidema, H.P. 1950. A new fossil insect and plant locality in Montana. Papers of the Michigan Academy of Sciences, Arts, and Letters 36: 119-123.
- Zuidema, H.P. 1955. Ancient wings in the rocks. Earth Science Digest 8(5): 14-18.